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TRW

Advanced X-ray Astrophysics Facility

Reliability Plan

Submitted to:
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, AL 35812

Submitted by:
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Reliability Plan

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TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

ACRONYMS

AXAF	Advanced X-ray Astrophysics Facility
CCB	Configuration Control Board
CDA	Critical Design Audit
CDC	Control Data Corporation
CDR	Critical Design Review
CEI	Contract End Item
CIL	Critical Items List
DCR	Design Conformance Review
ECH	Electronic Components Handbook
ECP	Engineering Change Proposal
EEE	Electrical, Electronic and Electromechanical
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EQ	Equipment Specification
ESD	Electrostatic Discharge
EVA	Extra Vehicular Activity
FAR	Failure Analysis Report
FAX	Facsimile
FMEA	Failure Modes and Effects Analysis
FRB	Failure Review Board
FRR	Flight Readiness Review
GFE	Government Furnished Equipment
GFP	Government Furnished Property
GIDEP	Government Interservice Data Exchange Program
GRO	Gamma Ray Observatory
GSE	Ground Support Equipment
ICD	Interface Control Drawing
OMV	Orbital Maneuvering Vehicle
ORI	Operations Readiness Inspection
OCLI	Optical Coating Laboratory Inc.
ORU	Orbital Replacement Unit
OMRSD	Operational and Maintenance Requirements and Specification Data
MDAC	McDonnell Douglas Aircraft Corporation
MIUL	Material Identification Usage List
MSFC	Marshall Space Flight Center
MTBF	Mean Time Between Failures
MTTR	Mean Time to Repair
MRB	Material Review Board
MUA	Material Usage Agreements
NASA	National Aeronautics and Space Administration
NCI	Nonconforming Item
PAR	Product Assurance Requirements
PC	Printed Circuit
PDA	Preliminary Design Audit
PDR	Preliminary Design Review
PIND	Particle Impact Noise Detection
PMP, PM&P	Parts, Materials, and Processes
PMPCB	Parts, Materials, and Processes Control Board
PRD	Project Requirements Document
PRR	Parts Replacement Record
QA	Quality Assurance

ACRONYMS (CONTINUED)

RDE	Response Design Engineer
RF	Radio Frequency
S&MA	Safety and Mission Assurance
S&TG	Space and Technology Group
SE	Systems Engineering
SPF	Single Point Failure
SRR	System Requirements Review
STS	Space Transportation System
S/W	Software
TDR	Test Discrepancy Report
TLM	Telemetry
TSTR	Troubleshooting Teardown Record

NOTES:
1. RELIABILITY PREDICTIONS HAVE BEEN DELETED (PAR. 3.3).

1 INTRODUCTION

1.0 APPROACH

The reliability effort employed by TRW and its subcontractors for the Advanced X-ray Astrophysics Facility (AXAF-I) will take into account various program-specific features of the hardware and software and the AXAF-I mission. These include:

a) AXAF-I has a 5 year mission.

b) A Shuttle abort would be the only AXAF-I return to Earth.

c) Extensive hardware heritage exists from Gamma Ray Observatory (GRO).

d) Science instruments are Government Furnished Equipment (GFE) but TRW has a participatory role in the review of their design.

e) The telescope has rigorous contamination control, mirror tolerance, thermal, bright object, and other sensitivities.

f) The AXAF-I must be capable of operating for 72 hours without ground intervention.

g) The usual single fault and two fault tolerance criteria for Shuttle programs are in effect.

The reliability program which will be implemented by TRW and its subcontractors to address these features is described in the sections which follow. This plan is submitted in response to AXAF-I Data Procurement Document DR PA05.

1.1 APPLICABLE DOCUMENTS

The following is a list of documents applicable to this plan.

Government

NHB 5300.4(1A-1)	Reliability Program Requirements for Aeronautical and Space System Contractors
NHB 5300.4(1D-2)	Safety, Reliability, Maintainability and Quality Provisions for the Space Shuttle Program
MSFC CR 5320.9	Payload and Experiment Failure Mode and Effects Analysis and Critical Items List Groundrules
MIL-HDBK-217F	Reliability Prediction for Electronic Equipment

Government (Continued)

NSTS 1700.7B	Safety Policy and Requirements for Payloads Using the Shuttle Transportation System
MIL-STD-975G	NASA Standard Electrical, Electronic, and Electromechanical Parts

TRW

	Electronic Components Handbook (ECH)
PAR 700-272	AXAF-I Subcontractor Product Assurance Requirements
	Reliability and Maintainability Handbook
PA07	AXAF-I EEE Parts Program Plan
SE04	AXAF-I Materials and Processes Control Plan
PA01	AXAF-I Quality Assurance Plan
SA03	AXAF-I Safety Plan
CM01	AXAF-I Configuration Management Plan
VR01	AXAF-I Verification Plan
D02700	TRW Subcontractor Derating Requirements

2 RELIABILITY PROGRAM MANAGEMENT

2.0 ORGANIZATION

The primary responsibility for the AXAF-I reliability program rests with the AXAF-I Reliability Manager (hereafter referred to as the project reliability manager). He reports project-wise to the AXAF-I Product Assurance Manager (Figure 2-1), who in turn reports to the AXAF-I Program Manager (Figure 2-2). Figure 2-2 illustrates that the AXAF-I Reliability Manager also reports functionally to the S&TG Reliability/Maintainability and Safety Manager in the TRW matrix management system. This assures consistency in applying reliability practices and provides a separate path for obtaining management attention where necessary.

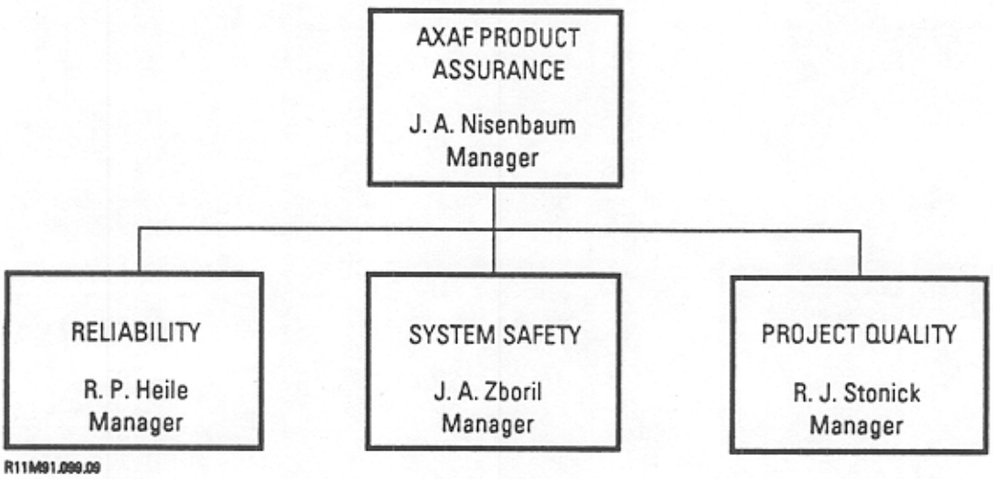

Figure 2-1 AXAF-I Product Assurance Organization Chart

Figure 2-2 AXAF-I Program Organization

2.1 RELIABILITY PLAN

This reliability plan describes how TRW will satisfy requirements listed in the AXAF-I Statement of Work and NHB 5300.4 (1A-1). The plan makes maximum use of standard TRW procedures and techniques contained in the TRW Reliability/Maintainability Handbook for cost effectiveness purposes. These reliability requirements will be imposed upon TRW's subcontractors and suppliers by PAR 700-272, AXAF-I Subcontractor Product Assurance Requirements (PAR), (hereafter referred to as the PAR document). This reliability plan is compatible with the AXAF-I Quality Assurance Plan, Safety Plan, EEE Parts Program Plan, Materials and Process Control Plan, and Verification Plan.

Figure 2-3 correlates the reliability task paragraphs of this plan to the applicable paragraphs of NHB 5300.4(1A-1).

Reliability Task	NHB 5300.4(1A-1) Section Number	Section Number in This Plan
Organization	1A200	2.0
Reliability Program Plan	1A201	2.1
Reliability Program Control	1A202	2.2
Reliability Progress Reporting	1A203	2.3
Reliability Training	1A204	2.4
Supplier Control	1A205	2.5
Use of Previously Designed, Fabricated, and Flown Hardware	1A206	2.6
Reliability of GFP	1A207	2.7
Design Specifications	1A301	3.1
Standardization of Design Practices	1A302	3.2
Reliability Prediction	1A303	3.3
FMEA's	1A304	3.4
Parts Stress Analysis	1A305	3.5
Worst Case Analysis	1A306	3.6
Trend Analysis	1A307	3.7
Special Analyses	1A308	3.8
Software Assurance	1A309	3.9
Maintainability/Serviceability & Human Induced Failure	1A310	3.10
EEE Parts	1A311	3.11
Materials & Processes	1A312	3.12
Review of EEE Packaging	1A313	3.13
Design Review Program	1A314	3.14
Problem/Failure Reporting & Correction	1A315	3.15
Reliability Evaluation Plan	1A401	4.1
Testing	1A402	4.2
Reliability Assessment	1A403	4.3
Reliability Inputs to Readiness Reviews	1A404	4.4
Reliability Eval. Program Reviews	1A405	4.5

Figure 2-3 Correlation of Sections of this Plan to NHB 5300.4(1A-1)

Figure 2-4 illustrates AXAF-I reliability activities phased with the major milestones of the AXAF-I program. Figure 2-5 shows the AXAF-I Program Reliability Schedule. (Note: This plan will not be updated for program schedule changes unless the plan is being otherwise revised.)

In response to the NHB 5300.4 (1A-1) reliability requirements, TRW has developed an AXAF-I Reliability Plan which:

- Emphasizes safety as a priority in the AXAF-I design.
- Provides early coordination with subcontractors to ensure flowdown and understanding of AXAF-I requirements.
- Performs Failure Mode and Effects Analysis (FMEA) examining all mission events, spacecraft actions, and system interfaces.
- Identifies single-point failure and two fault tolerance areas of concern.

Figure 2-4 Reliability Activities by Program Phase

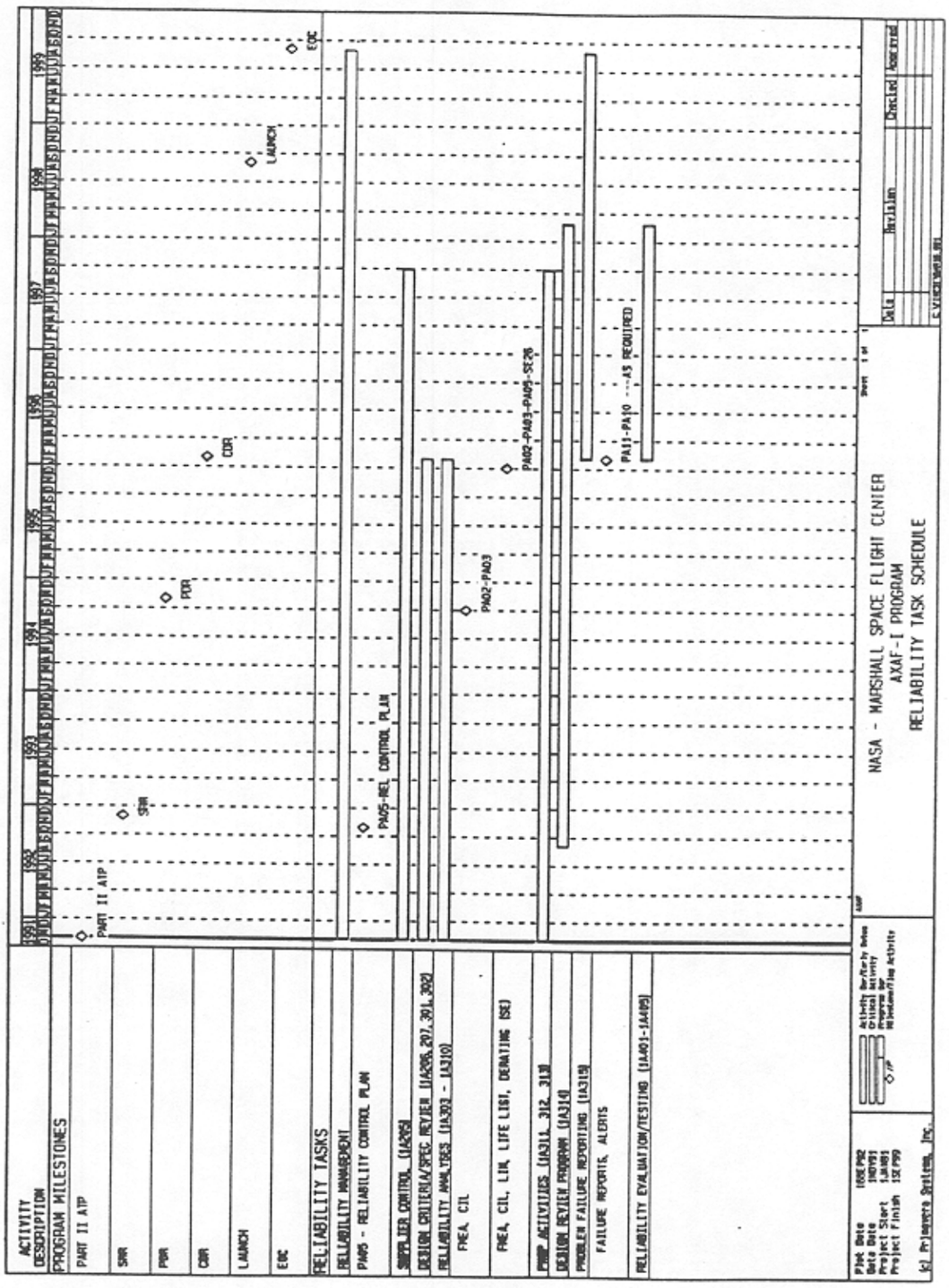

Figure 2-5 AXAF-I Reliability Task Schedule

Figure 2-6 illustrates the responsibilities of other project disciplines in implementing the provisions of the AXAF-I Reliability Plan. The following sections describe the division of responsibilities amongst AXAF-I Reliability personnel:

AXAF-I Reliability Manager

a) Establish AXAF-I project reliability policies,procedures, etc.

b) Prepare the AXAF-I Reliability Plan (PA05).

c) Review progress against schedule and cost milestones.

d) Support the overall AXAF-I design review program.

e) Provide reliability support for subcontractor monitoring activities.

f) Direct and monitor the performance of in-house reliability tasks and initiate corrective action where necessary.

g) Review all communications with the customer which affect reliability.

h) Participate in negotiations with the customer on contract commitments, changes, and cost estimates pertaining to reliability.

i) Provide reliability inputs for design tradeoff purposes.

j) Direct the performance of the FMEAs and Critical Items List (PA02 and PA03).

k) Direct the generation of the Limited Life Items List (PA06).

l) Act as chairman of the AXAF-I Failure Review Board (FRB).

m) Direct the problem/failure reporting and corrective action activities

n) Assure the generation of Nonconformance and Resolution Reports (PA11).

o) Investigation of Alerts.

RELIABILITY PROGRAM TASK (NHB 5300.4 (1A1) PARAGRAPH)	TRW RESPONSIBLE ORGANIZATION(S)	SCHEDULE OF COMPLETION	INTERFACES WITH OTHER ELEMENTS OF TRW PROJECT ORGANIZATION
RELIABILITY MANAGEMENT (1A201, 202, 203, 204)	RELIABILITY	REL PLAN AT SRR; CONTINUOUS	PMP, QUALITY, SAFETY, TEST, INTEGRATION, SUBCONTRACT ADMINISTRATOR, MATERIAL, SE, SOFTWARE, DESIGN ENGINEERING
SUPPLIER CONTROL (1A205)	PRODUCT ASSURANCE	CONTINUOUS THROUGH DELIVERY OF HARDWARE	QUALITY, SUBCONTRACT ADMINISTRATOR, DESIGN ENGINEERING
DESIGN CRITERIA & SPECIFICATIONS (1A206, 207, 301, 302)	RELIABILITY, DESIGN ENGINEERING	CONTINUOUS	PMP, QUALITY, SAFETY, TEST, DESIGN ENGINEERING, SUBCONTRACT ADMINISTRATOR, SE, SOFTWARE
RELIABILITY ANALYSES (1A303, 304, 305, 306, 307, 308, 309, 310)	RELIABILITY	PRELIMINARY AT PDR. FINAL CDR. UPDATES AS NEEDED	PMP, SAFETY, TEST, DESIGN ENGINEERING, SUBCONTRACT ADMINISTRATOR, DESIGN ENGINEERING, SE, SOFTWARE
PARTS CONTROL (1A311)	PARTS, QUALITY	CONTINUOUS THROUGH LAUNCH	SUBCONTRACT ADMINISTRATOR, MATERIAL, DESIGN ENGINEERING
MATERIALS AND PACKAGING REVIEW (1A312, 313)	MATERIALS AND PROCESSES, QUALITY	CONTINUOUS THROUGH LAUNCH	DESIGN ENGINEERING, THERMAL, SUBCONTRACT ADMINISTRATOR, PRODUCT ENGINEERING
DESIGN REVIEW (1A314)	RELIABILITY, PROJECT OFFICE, DESIGN ENGINEERING, SAFETY, QUALITY	PER PROJECT MILESTONE SCHEDULE	DESIGN ENGINEERING, QUALITY, PMP, TEST, SAFETY, INTEGRATION, SUBCONTRACT ADMINISTRATION, SE, SOFTWARE
PROBLEM/FAILURE REPORTING (1A315)	RELIABILITY, QUALITY	CONTINUOUS THROUGH LAUNCH	QUALITY, DESIGN ENGINEERING, SUB-CONTRACT ADMINISTRATOR, INTEGRATION, TEST, MANUFACTURING, PMP, SAFETY, SE, SOFTWARE
TEST SURVEILLANCE (1A401, 402, 403, 404, 405)	RELIABILITY, QUALITY	CONTINUOUS THROUGH DELIVERY OF HARDWARE	TEST, DESIGN ENGINEERING, QUALITY, SAFETY, SUBCONTRACT ADMINISTRATOR, MATERIAL, PMP, SE, SOFTWARE, MAINTAINABILITY
ALERTS (PA10)	RELIABILITY, SAFETY, PARTS, MATERIALS, AND PROCESSES	CONTINUOUS THROUGH LAUNCH	SUBCONTRACT ADMINISTRATOR, QUALITY, DESIGN ENGINEERING
LIMITED LIFE ITEMS (PA06)	RELIABILITY	LIST PER PA06 AT CDR. TRACKING THROUGH LAUNCH	TEST, DESIGN ENGINEERING, QUALITY, SUBCONTRACT ADMINISTRATOR, PMP, SE

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Figure 2-6 Responsibility for Reliability Program Tasks

AXAF-I Reliability Engineers

AXAF-I Reliability engineers provide reliability engineering support as directed by the project reliability manager. The primary objectives are:

a) Utilization of reliability design analysis techniques to assure inherent reliability of the hardware and software.

b) Providing reliability analyses for tradeoff studies.

c) Review design and test specifications.

d) Preparation of failure modes and effects analysis and critical item list.

e) Preparation of the Limited Life Items List.

f) Problem/failure investigation, documentation and corrective action tasks.

g) Review of parts derating compliance with project criteria.

h) Provide inputs to and participation in design reviews and audits.

i) Conduct of sneak circuit analysis and hardware-software interface analysis where necessary.

j) Subcontractor surveillance activities.

k) Special attention controls review.

l) Review alerts.

Data Requirement submittal for which Reliability personnel have primary responsibility are listed in Section 2.8. Submittal schedules, MSFC Review/Approval requirements, and TRW Review/Approval authorities are identified in Section 2.8.

As shown in the AXAF-I Product Assurance Organization Chart of Figure 2-1, the Safety discipline reports to the same manager as does Reliability. The FMEA activity is performed by Reliability personnel and serves as a partial verification of the fault tolerance requirements for Safety. Likewise, the hazard analysis performed by Safety personnel assists in the review of combinational failure modes by Reliability.

In addition to Safety, other disciplines which support the Reliability program include:

- Parts, Materials, and Processes - perform failure analysis; perform part and materials selection, specification, qualification, and application reviews.

- Design Engineering - provide stress levels; do worst case analysis; prepare design review packages; provide support to FMEAs; perform trouble-shooting of nonconformances.

- Quality Assurance - provides subcontractor monitoring; initiates nonconformance reports; maintains operating time logs.

2.2 RELIABILITY PROGRAM CONTROL

Reliability budgets and expenditures are reported to MSFC in PM03, AXAF-I Monthly Cost and Schedule Report. TRW internal controls include reliability subproject reviews which present cost, schedule, task progress, and potential problems to management. The local MSFC representative is invited to these meetings.

Independent audits of the AXAF-I reliability effort are conducted by TRW PA management on an approximate yearly basis.

Surveys and audits of subcontractor reliability activities are conducted periodically by QA personnel and QA source inspection personnel.

2.3 RELIABILITY PROGRESS REPORTING

Weekly telecons are held with the MSFC S&MA Manager to report activities and progress in the Product Assurance disciplines.

Quarterly status reviews are held with MSFC by TRW AXAF-I program personnel.

2.4 RELIABILITY TRAINING

The AXAF-I reliability effort will employ reliability personnel who have previous experience with much of the hardware and many of the subcontractors used on AXAF-I. Likewise, experience with the AXAF-I FMEA and CIL requirements exists due to these personnel utilizing similar procedures on OMV for MSFC. Any additional training required will be obtained from the S&TG Reliability/Maintainability and Safety Skill Center which has an extensive library of training videotapes and handouts.

The unique aspect of AXAF-I (mirror handling and sensitivity) has been addressed beginning with Part I of the AXAF-I Program by a combination of TRW and subcontractor Quality and Safety personnel who have reviewed ORI documentation to protect the integrity of the mirror elements during processing and handling.

2.5 SUPPLIER CONTROL

Figure 2.7 identifies potential subcontractors and suppliers of hardware for AXAF-I. The product assurance requirements imposed upon subcontracted hardware are contained in PAR 700-272, AXAF-I Subcontractor Product Assurance Requirements. The PAR document

AXAF-I Equipment	Possible/Potential Subcontractor/Supplier
Telescope System	Eastman Kodak
Mirror Elements	Hughes Danbury Optical Systems
Mirror Optical Coating	To Be Determined
Fine Sun Sensor Assembly	Adcole
Bright Object Detector	Ball
Radiation Detector	Ball
Aspect Camera	Ball
Science Instrument Module	Ball
On-Board Computer	Computing Devices Int'l (CDC)
Command and Data Management	Gulton
Earth Sensor Assembly	Ithaco
Reaction Wheel Assembly	Teldix
Solar Array Substrate	Fokker
Battery Cells	Eagle-Picher
Solar Cells	Applied Solar Energy Corp.
Cell Covers	Optical Coating Labs, Inc.
Transponder, Power Amp, Diplexer, and RF Switch	Motorola, Loral, or Cubic
Inertial Reference Unit	Kearfott
Superzip or Sure Sep.	Lockheed or McDonnell Douglas
Bolt Cutter/Separation Nut	Holex

Figure 2.7 AXAF-I Potential Subcontractors/Suppliers

and the individual Equipment Specifications and Statements of Work define project reliability requirements and tasks for subcontractors. Suppliers (as contrasted with subcontractors) are controlled through applicable product assurance requirements on Purchase Orders and Specification Control Drawings.

Specific tasks performed by TRW reliability personnel relative to subcontractors include:

- Support to subcontractor selection and fact-finding.
- Review of subcontractor reliability program plans.
- Review and approval of subcontractor analyses. These include tradeoff studies, stress analyses, failure mode and effect analyses, trend analyses, and design life analyses.
- Participation in subcontractor PDA and CDA.
- Review of critical item control procedures.
- Review of monthly status reports.
- Monitoring of subcontractor failure-reporting activities.

Subcontractor design audits/reviews will be held for equipment for which the subcontractor has design cognizance. The requirements are generally the same as for TRW component-level reviews. The reviews will be held at the subcontractors' facilities. TRW will co-chair the reviews with the subcontractor and will employ its own committee, including selected design specialists, to critique the design. The subcontractor will provide committee members and will supply the technical secretary. The subcontractor is responsible for the preparation and generation of all design review documentation. The subcontractor design data package requirements are listed in the PAR documents. TRW must approve the meeting notice/agenda, meeting minutes, action item responses, and close-out action. MSFC personnel will be invited to attend subcontractor design audits/reviews.

2.6 PREVIOUSLY DESIGNED, FABRICATED, AND FLOWN HARDWARE

AXAF-I makes extensive uses of hardware previously flown on GRO. Some of this hardware will be qualified for AXAF-I by similarity to GRO. Most of the remaining hardware will be protoflight-tested. A description of how each hardware item is tested is contained in the AXAF-I Verification Plan (VR01). TRW Reliability Engineering will be one of the reviewers of this heritage data as presented at component design reviews. Where qualification-by-similarity is intended, the focus will be on differences between the environment previously qualified to and the AXAF-I mission. Also, any hardware changes will be carefully scrutinized for effect on previous qualification.

Responsibilities for presenting previously designed, fabricated and flown data is that of the Responsible Design Engineers.

2.7 RELIABILITY OF GOVERNMENT FURNISHED PROPERTY (GFP)

Where reliability characteristics of GFP must be known by TRW (such as for system FMEA interface purposes), the AXAF-I GFP Manager will request the pertinent information of MSFC. If TRW detects any apparent deficiencies in the reliability of GFP, MSFC will be promptly provided the pertinent documentation. GFP failures at TRW will be reported to MSFC for disposition. Handling and identification of GFP items is contained in the GFP Plan (LS03).

2.8 DATA REQUIREMENT SUBMITTAL

AXAF-I Reliability personnel have primary responsibility for the following Data Requirement (DR) submittal:

Data Requirement	DR NO.	Submittal Schedule	Type of Data	TRW Review/ Approval
Reliability Plan	PA05	3 wks before SRR	1	AXAF-I Program AXAF-I PA Mgr., S&TG R/M/S Skill Center Manager
FMEA	PA02	3 wks before PDR & CDR; updates as necessary	2	AXAF-I Program AXAF-I PA Manager
Critical Items List	PA03	3 wks before PDR & CDR; updates as necessary	2	AXAF-I Program AXAF-I PA Manager
Limited Life Items List	PA06	3 wks before CDR; updates as necessary	2	AXAF-I Program AXAF-I PA Manager
Nonconformance Reports	PA11	Notification within 1 working day; Report within 5 working days; Closeout within 21 calendar days	3	Review/Approval via Failure Review Board

NOTE: ALERTS (PA10) and EEE Parts Application (SE26) are the primary responsibility of PM&P and System Engineering respectively. Reliability provides support to each.

3 RELIABILITY ENGINEERING

3.0 GENERAL

The sections which follow describe analyses and surveillance efforts aimed at assuring the reliability of AXAF-I throughout the design, fabrication, test, and mission phases of the program.

3.1 DESIGN SPECIFICATIONS

TRW will prepare CEI, ICD, EQ Specifications, etc., in accordance with the AXAF-I Configuration Management Plan.

All documentation applicable to design, procurement, test, and assembly will be subject to reliability input and review. System, environmental, and equipment specifications will include specific reliability criteria to guide design and test, as well as adequate quality assurance criteria to preserve inherent reliability. Maintenance of these specifications will be provided through the application of configuration management practices as outlined in the Configuration Management Plan to protect against changes detrimental to overall reliability objectives and to provide complete accountability of configured end items. Specifications found by Reliability to be unsatisfactory will not be approved by the AXAF-I Product Assurance Manager until recommended changes are incorporated.

3.1.1 Specifications Review

Reliability personnel review each design specification to ensure flowdown of the AXAF-I reliability requirements.

Items which receive special attention are:

- Life requirement and limited life item tracking
- Fault tolerance requirement
- Worst case analysis requirement
- Derating requirement
- Fault isolation requirement
- Qualification provisions
- Critical item (handling) requirements
- Redundancy and cross-strapping provisions
- Overall environmental test profile (vibration, multiple temperature cycles, and thermal vacuum, as applicable) and key parameter tracking requirements
- Failure reporting requirements
- Redundancy and alternate path testing

3.1.2 Review of Changes

Reliability personnel participate in the Configuration Control Board (CCB) and review all changes for reliability impact.

3.2 STANDARDIZATION OF DESIGN PRACTICES

MSFC has identified specific process specifications to be applied for AXAF-I. TRW has previous experience with these documents and TRW standard practices comply in most instances. Material Usage Agreements (MUAs) and the Material Identification Usage List (MIUL) generated by Materials and Processes will be provided. Processing requirements will be flowed down to AXAF-I subcontractors. (Reference: AXAF-I Materials and Processes Control Plan).

3.3 RELIABILITY PREDICTION

TRW will perform reliability predictions for AXAF-I where necessary to support tradeoff analysis. MIL-STD-217 will be used as the failure rate database. Predictions made for this purpose will be presented at design reviews. Reliability block diagrams, failure detection provisions, and failure criticality will be reflected in the FMEA/CIL. Wearout related parameters will be reflected in the Limited Life Items List.

3.4 FAILURE MODES & EFFECTS ANALYSIS (FMEAs)

3.4.1 FMEA Procedure

FMEAs will be performed on AXAF-I in accordance with DR PA02 and MSFC CR 5320.9, Payload and Experiment Failure Mode and Effects Analysis and Critical Items List Groundrules.

Submittal will be three weeks prior to PDR and CDR, with updates as needed (generally as part of CCB documentation). The scope of the FMEA includes the AXAF-I, GSE during the launch countdown, and control/support software. Objectives of the FMEA will be to assure that:

- No two credible failures result in loss of life or damage to the orbiter.
- No single credible failure produces a loss of STS, loss of the STS mission, loss of AXAF-I, or AXAF-I's mission. (Also, no single failure removes the ability to monitor at least one of the safety inhibits provided for critical and catastrophic functions.)

Critical items identified by the FMEA will be subject to Critical Item Control as specified in CR 5320.9.

A system-level FMEA will be performed for PDR. This will examine the AXAF-I system elements, their functions, and the events occurring during all mission phases. Failure modes will be identified for each component during each mission phase. This analysis is performed down to the component (black box) level, and within components where necessary to identify critical functions.

Criticality Categories will be as follows:

Category	Definition
1	Single failure point resulting in loss of life or carrier vehicle.
1R	Redundant hardware elements the failure of which could cause loss of life or carrier vehicle.
1H	Single failure point rendering inoperative a system designed to monitor hazards or a system used to react to hazards; such hazards being sufficient to cause potential loss of life or carrier vehicle.
1HR	Redundant hardware elements the failure of which renders inoperative a redundant system designed to monitor hazards or react to hazards; such hazards being sufficient to cause potential loss of life or carrier vehicle.
2	Single failure point of payload/experiment hardware resulting in loss of carrier vehicle mission.
2R	Redundant hardware elements the failure of which could cause loss of carrier vehicle mission.
2P	Single failure point resulting in loss of payload/experiment hardware or loss of payload/experiment mission objectives.
2PR	Redundant hardware elements the failure of which could cause loss of hardware or mission, as specified in category 2P above.
3	All others.

The FMEA will include a summary of groundrules applied; it will identify the scope of the analyses; and it will include schematics, block diagrams, descriptive material, FMEA code designators, and an index of results. FMEAs will be performed by Reliability Engineering and reviewed by Systems Engineering and/or the RDEs. The individual FMEA worksheets (see Figure 3.4-1) will contain the following information:

1. Item Description - Each component will be identified by system, subsystem, component name and part number, quantity performing the same function, drawing or schematic reference, flow diagram, block diagram or description reference and FMEA item code. A concise statement of the function performed will be provided.

2. Failure Mode and Primary Cause - The postulated failure mode will consider untimely operation as well as non-operation. Major failure causes such as thermal, contamination,

micrometeoroids, radiation, vibration, shorts, etc. will be listed for inspection and test planning purposes. Criticality of each failure mode will be listed in parentheses.

3. Failure Effects - Failure effects on AXAF-I, its mission, and on the Orbiter and flight or ground crews will be identified.

4. Applicable Phase - Beginning with prelaunch activity and ending with mission completion.

5. Hardware Criticality Category - 1, 1R, 1H, 1HR, 2, 2R, 2P, 2PR, or 3. Rationale for the criticality assignment will be provided. The worst case failure mode criticality will be assigned as the hardware criticality.

6. Redundancy and Corrective Action - Identifies the type of redundancy or corrective action available. Indicates how the redundancy is activated.

7. Detection Method & System Response Time - Illustrates the detection method and the time available until a critical failure effect, time to detect, and time to correct. The first of the three time parameters shall be greater than the sum of the other two. Time to correct shall include delays in initiating corrective action.

8. Pass or Fail for the following three Redundancy Screens -

   a) The redundant elements are capable of checkout during preparations at the launch site.

   b) Loss of a redundant element is readily detectable by the flight or ground crew (not applicable to items in inactive standby).

   c) All redundant elements will not be lost due to a single credible cause or event, such as contamination or explosion.

9. Software Response - For hardware failure modes impacting software or firmware, a reference to the applicable Hardware/Software Analysis item number.

10. Criticality 1R Two Fault Tolerance - For all Criticality 1R item, identifies whether two fault tolerance exists to preclude the designated safety hazard.

11. Remarks - Pertinent remarks such as hazards, recommendations. Identifies hazards contained in the System Hazards Analysis.

12. Identification of FMEA preparer, approver, page, date and revision.

Criteria used in performing the FMEA will include:

A) Fire/Explosion - The FMEA will address "worst-case" effects. Criticality designation will reflect "worst-case" potential effect of the failure mode. This includes possible catastrophic effects such as fire/explosion as well as effects of loss of hardware functions regardless of probability of occurrence. Single failures such as leakage of N_2H_4 in presence of a possible ignition source will be listed as potential fire/explosion and classified as Criticality 1 single failure point (SFPs). (Exclusion due to environments nonsupportive of combustion will be explained).

B) Structures - Structures will be excluded from the FMEA, with the exception of the items listed below:

a) Pressure vessels*, component housings, mechanical bellows, rupture discs, fluid lines, and their attached fittings.

* Pressure vessels as defined by NSTS 1700.7B.

b) Structural hardware with movable, pivoting, sliding, expansion, or flexible joints or mechanisms which grasp or release.

c) Items which have a single mechanical barrier between oxidizer and fuel/combustible gas or fluid.

d) Items that are known to develop "acceptable defects" within their allowed time for usage, will be analyzed for worst case defect propagation.

e) Items having internal cavities which can induce an internal overpressure from migrating fluid because of leak from inside or outside.

f) Attach/interface hardware which is designed to fracture/separate (e.g., separation bolts, tension straps).

g) All welded or brazed joints. Inspectability after proof or stress testing will be noted.

h) Housing which must contain vacuum, pressure, high energy, or fragmentation products (such as reaction wheels).

PAGE ____ OF ____
PREPARED BY: _____ DATE _____
APPROVED BY: _____ REV _____

TRW — AXAF HARDWARE FAILURE MODE & EFFECTS ANALYSIS (FMEA)

SYSTEM:
SUBSYSTEM/ASSY:
COMP./EQUIPMENT:
P/N: QTY:
DWG/SCHEMATIC:
REFERENCE:

MISSION PHASES
____ (1) PRE-LAUNCH
____ (2) LAUNCH/REENTRY
____ (3) DEPLOY
____ (4) MANUEVER
____ (5) ORBITAL OPS
____ (6) STS ABORT

CRITICALITY (BASED ON FUNCTION)
1 LIFE, STS LOSS
1H HAZARD MONITOR LOSS
2 STS MISSION LOSS
2P AXAF/AXAF MISSION LOSS
3 ALL OTHERS
R ADD FOR REDUNDANCY

FMEA ITEM CODE	FUNCTION/DESCRIPTION REFERENCE DESIGNATION/ CRITICALITY	FAILURE MODE/CAUSE	FAILURE EFFECTS (A) AXAF (B) ORBITER/AXAF MISSION (C) ORBITER/CREW (CRIT.)	SYSTEM RESPONSE (D) TYPE OF REDUNDANCY OR CORRECTIVE ACTION (E) DETECTION METHOD & REACTION TIME (F) S/W FMEA ITEM NUMBER	OTHER (G) CHECKOUT AT LAUNCH PAD (H) FAULT DETECTABLE (I) NO COMM. MODE FAILURE (K) CRIT 1R TWO FAULT TOL. (L) REMARKS (M) REFERENCE HAZARD NO.
		FAILURE MODES:	(A) AXAF HARDWARE	(D) REDUNDANCY OR C/A:	(G) REDUNDANCY CHECKOUT AT LAUNCH PAD: P: F: N/A
					(H) REDUNDANCY LOSS DETECTABLE BY FLIGHT OR GROUND CREW: P: F: N/A
		FAILURE CAUSES:	(B) ORBITER OR AXAF MISSION		(I) SINGLE CAUSE/EVENT WON'T PRODUCE LOSS OF ALL REDUNDANCY P: F: N/A
				REDUNDANCY ACTIVATION: OPERATIVE: GROUND: AUTONOMOUS::	
				(E) DETECTION METHOD:	(K) CRIT 1R TWO FAULT TOL: YES: NO: N/A:
	CRITICALITY:		(C) ORBITER/CREW		(L) REMARKS:
	RATIONALE:			TIME UNTIL CRITICAL EFFECT: SYSTEM RESPONSE TIME TO DETECT: TIME TO CORRECT:	
				(F) S/W FMEA ITEM NO:	(M) HAZARD NO:

R11M91.099.15

Figure 3.4-1 AXAF-I Hardware Failure Mode & Effects Analysis (FMEA)

C) Leakage - Leakage at all joints except inspectable welded or brazed joints will be analyzed. The analysis will consider effect of a leak impinging on flammable surfaces or components.

D) Electrical Cables - Each cable assembly will be reviewed to identify critical signals (failure effect 2PR and above) and will be analyzed for open circuits, short circuits,and complete loss of connector. Adjacent pins carrying critical signals which if shorted could generate an improper or untimely operation will be analyzed.

E) Common Functions - Only one element will be analyzed when the only difference is in location. Where several components perform the same functions and have the same effects, they may be listed collectively (e.g., electrical harnesses, lines/ducts, and seals).

F) Interface - The analysis will include the loss of inputs and outputs across major element interfaces, such as from the STS to AXAF-I and vice versa.

G) Government Furnished Equipment - Hardware supplied as GFE will be analyzed by the designers of the GFE. The analysis of loss of a GFE interface function will be provided by TRW.

H) Orifices - Blockage of orifices will be considered a valid failure mode and/or cause.

I) Timely Operation - All component failure modes will be listed, giving consideration to the following conditions, where applicable:

- o Premature operation
- o Failure to operate at a prescribed time
- o Failure to cease operating at a prescribed time
- o Failure during operation

Launch scrub is not classified as "critical".

J) Reaction Time - The analysis will determine the time for the failure effect to occur and this will be specified in units of time, i.e., milliseconds, seconds, etc. If a detection method is available, it will be identified and its response time to safely correct identified. If a detection system is available but would not safely correct, then this will be so noted.

K) Criticality of components - The analysis will consider loss of function of a component without regard for redundancy in establishing numerical criticality categories.

L) Criticality "R" Assignments - An "R" is added to the numerical criticality category under the following condition:

- o There is like redundant hardware or an unlike redundant hardware (non-emergency back-up) path that will accomplish the same function.

M) Emergency Systems - Emergency or contingency safing hardware will be analyzed on a stand-alone basis in assigning its criticality. Such hardware will not be considered as redundancy in assigning criticality categories to other hardware elements.

N) Combinations of Failures - Combinations of systems failures will be analyzed to assure two fault tolerance to potential hazards.

O) GSE - AXAF-I GSE used on Criticality 1, 1R, 1H, 1HR, 2, and 2R hardware during the launch countdown will be analyzed. The Hazard Analysis will assist in this task.

P) Supplier FMEAs - Supplier and Subcontractor FMEA results will be integrated into the system FMEA analysis.

Q) FMEA/CIL Submittal - The FMEA and CIL will be submitted to MSFC for PDR and CDR as specified in DR's PA02 and PA03. Subsequent design changes or program data necessitating revisions to the FMEA/CIL will be provided to MSFC as part of Configuration Control Board or Failure Review Board documentation.

For CDR, the FMEA examines individual assemblies to ensure that the detail implementation of the design (e.g., internal redundancy, printed circuit (PC) traces, connector pin assignments) will not introduce safety-critical or single point failure modes. This phase of the FMEA examines pinouts, assembly interfaces, redundancy switching, fault isolation, and physical locations where redundant paths are in proximity. In addition, the FMEA at CDR reflects the design evolution since PDR.

The following design areas will be investigated during this phase of the FMEA:

- o Single wires, single printed circuit (PC) traces, single solder joints, single plated-through holes, or single connector pins which may negate system redundancy.
- o Unsupported plated-through holes.
- o PC traces close to heat generating parts.
- o Spacing between adjacent PC traces and separation between redundant traces.
- o PC trace current-carrying capacity.
- o PC board artwork vs. schematic diagram-indicated redundancy.

- Single ground points and ground trace intersections at board edge.
- Connector pin and slip ring adjacency assignments.
- Cable shorts-to-chassis that are single-point failures.
- Primary and redundant functions sharing the same piece-part.
- Fault isolation.
- Open power daisy chains.
- Command matrix assignments (redundant commands in same row or column).
- Cascading or propagating failures.
- Converter overvoltage/undervoltage effects.
- Sneak paths (see Section 3.8).
- Premature or untimely operation.
- Failures affecting redundant paths in the same subsystem or work-around paths in another subsystem (including those impacting the command path and negating redundancy switching).
- Secondary circuit failures (such as telemetry) which can impact critical paths.
- Failures in cross-straps or switching circuits which may negate the design redundancy.

Piece part-level FMEAs will be performed prior to CDR for any items with Criticality Levels 1, 1H, 2, or 2P.

A Hardware/Software Analysis will be prepared separately from the Hardware FMEA. It will be conducted between PDR and CDR and will analyze the impact of hardware failures upon all software and firmware which directly supports or controls AXAF-I and its mission. It will include hardware/software interfaces and human/software interfaces. The analysis will identify how the software detects a hardware failure, its response, and whether the response meets system objectives. Figure 3.4-2 illustrates the AXAF-I Hardware/Software Analysis form to be utilized.

PAGE ___ OF ___
DATE _____
REV _____

PREPARED BY: _____
APPROVED BY: _____

TRW — AXAF HARDWARE/SOFTWARE ANALYSIS

SYSTEM: AXAF
SUBSYSTEM/SOFTWARE SEGMENT:
COMP/EQUIPMENT:
DESIGN REQUIREMENT:
REFERENCE:

MISSION PHASES
___ (1) PRE-LAUNCH
___ (2) LAUNCH/REENTRY
___ (3) DEPLOY
___ (4) MANUEVER
___ (5) ORBITAL OPS
___ (6) STS ABORT

CRITICALITY (BASED ON FUNCTION)
1 LIFE, STS LOSS
1H HAZARD MONITOR LOSS
2 STS MISSION LOSS
2P AXAF/AXAF MISSION LOSS
3 ALL OTHERS
R ADD FOR REDUNDANCY

HDWE FMEA ITEM CODE	FUNCTION	FAILURE MODE/EFFECTS	CRIT	SOFTWARE REQUIREMENTS (A) METHOD OF DETECTION IN S/W (B) REACTION TIME OF S/W (C) S/W RESPONSE TO HARDWARE FAILURE (D) S/W REQMTS DOCUMENT PARAGRAPHS

R11M91.099.14

Figure 3.4-2 AXAF-I Hardware/Software Analysis Form

The following information is provided on the Hardware/Software Analysis form of Figure 3-4-2:

A. Hardware subsystem and software segment names.

B. Component which is assumed to have failed.

C. Software design requirements document paragraph.

D. Reference documentation identification.

E. Preparer and approval authority.

F. Page, date, and revision.

G. Mission phase(s) and criticality of the hardware failure.

H. Software function.

I. Hardware failure mode and effects, including FMEA code identifier.

J. Method of detecting the hardware failure in the software (out-of-limit check, redundancy management algorithm, error code, interrupt, etc.)

K. Software reaction time to respond to the failure.

L. Software response (error notification, hardware command, system reconfiguration, etc.)

M. Where applicable, a correlation to a specific S/W Requirements Document paragraph will be provided.

3.4.2 Critical Items List

A Critical Items List (CIL) per DR PA03 will be generated from the results of the FMEA. It will contain two sections as follows:

A. Single Point Failure (SPF) Summary - Criticality categories 1, 1H, 2, and 2P. (Also any Criticality 1R items that are not two fault tolerant).

B. Critical Redundant Item Summary - Criticality categories 1R, 1HR, 2R, and 2PR.

The following information will be included on individual sheets (Figure 3.4-3) for each critical failure mode of each item identified as either a single point failure or a critical redundant item:

CIL PAGE: _____
REVISION: _____
DATE: _____

TRW AXAF CRITICAL ITEMS LIST (CIL)

(1) SYSTEM/SUBSYSTEM _____ (7) PART NAME _____
(2) FUNCTION _____ (8) PART NO. _____
(3) FMEA ITEM CODE & PAGE _____ (9) PHASE (S) _____
(4) ANALYST _____ (10) QUANTITY _____
(5) APPROVED BY _____ (11) EFFECTIVITY _____
(6) CRIT. CATEGORY _____ (12) HAZARD REF. _____

(13) FAILURE MODE AND EFFECT:

(14) FAILURE CAUSE (S): a.

b.

(15) REDUNDANCY SCREENS: SCREEN A _____ SCREEN B _____ SCREEN C _____
(PASS/FAIL AND EXPLAIN AS NECESSARY)

(16) RATIONALE FOR RETENTION:
(16A) DESIGN:
a.

b.

(16B) TEST:
a.

b.

(16C) INSPECTION:
a.

b.

(16D) FAILURE HISTORY/RELATED EXPERIENCE:
a.

b.

(16E) OPERATIONAL USE:
a.

b.

Figure 3.4-3 AXAF-I Critical Items List (CIL)

R11M91.099.13

A. Reference to applicable FMEA item code and FMEA page number.

B. Name of system or subsystem.

C. Part name, part number, quantity, effectivity.

D. Criticality category and phase(s).

E. Reference to hazard analysis.

F. Failure mode and effects (one failure mode per sheet).

G. Failure causes (rationale for retention will address each failure cause separately).

H. Redundancy screens.

I. Rationale for retention and recommendations to reduce the failure effect or to control the resulting conditions will be provided for all Criticality 1, 1H, 2, or 2P items and for any 1R, 1HR, 2R, and 2PR items that fail to pass any of the three redundancy screens of Section 3.4.1, item 8 and for any 1R items that are not two fault tolerant.

J. CIL page number, revision, and date.

K. Name of analyst and approval authority.

The rationale for retention data will address the following considerations:

a) Design - Will identify design features which minimize the probability of occurrence of the failure mode and causes. Will identify specific characteristics and controlling aspects in the design such as appropriate safety factors, the use of special materials, unique physical/chemical properties, critical dimensions as appropriate, and other measurable parameters under control that precludes or minimizes the probability of occurrence of the particular failure mode/cause for which the rationale is being presented. The redundancy configuration will be described as well as the effect of each succeeding failure.

b) Test - Will identify and describe specific testing (including check-out) that will be accomplished which supports the premise that the critical failure mode/cause for which the CIL is written has been properly addressed. Will identify when the last test is conducted prior to launch. Will reference applicable Operations and Maintenance Requirements and Specifications (OMRSD) tests.

c) Inspection - Will identify the specific inspection points (including mandatory) -- contractor,

subcontractor, and Government Agency -- and the critical process controls performed which minimize the probability that the failure mode causes will occur in the critical item. Will relate the inspection points to the failure mode cause.

d) Failure History - Provides a listing of all criticality categories 1, 1R, 2, 2P, 2PR, and 2R failures, causes, and the corrective actions beginning with acceptance testing. Verifies that failure and unsatisfactory condition report data does not show any undesirable trends.

e) Operational Use - Describes effect of the failure on operations, actions which the crew can take after the failure, crew training required, and any mission constraints. Describes checkout actions available to determine that the failure has occurred.

The CIL will be maintained by change page or complete revision. Design changes effecting function, redundancy, criticality, etc. will require that the CIL be updated to show the current status.

The AXAF-I Configuration Control Board function will assure that the critical item status is not changed without MSFC approval.

A CIL Index will be included which lists on a line item basis the FMEA item code, name, part number, criticality, quantity, redundancy screen status, includes an asterisk for any fault tolerance violations, and shows the count of critical items by subsystem.

3.4.3 Special Attention Controls

In addition to the controls associated with the Critical Items List, special attention controls are applied in two other areas:

3.4.3.1 Limited Life Items

Reliability personnel, in conjunction with Parts and Materials Engineering, System Engineering, and the Responsible Design Engineers, will identify all AXAF-I hardware having time/cycle limitations, expendables, environmental sensitivities, or other limited life characteristics. The limited-life items list will be used for two purposes:

a) To illustrate margins between life ratings and planned usage on AXAF-I for presentation at the Critical Design Review and Flight Readiness Reviews.

b) To track accumulated operating time/cycles for maintainability/servicing purposes.

DR PA06, Limited Life Items List, will be submitted three weeks prior to CDR, and will reflect allowable time/cycles, maximum

pre-flight time/cycles, and expected accumulated ground/flight time/cycles for all limited life items. Quality Assurance personnel will record accumulated time/cycles in the Component Test Records and the Integration and Test Running Time Log. Flight usage will be tracked by Mission Operations personnel. Figure 3.4.3.1 illustrates the Limited Life Item tracking form.

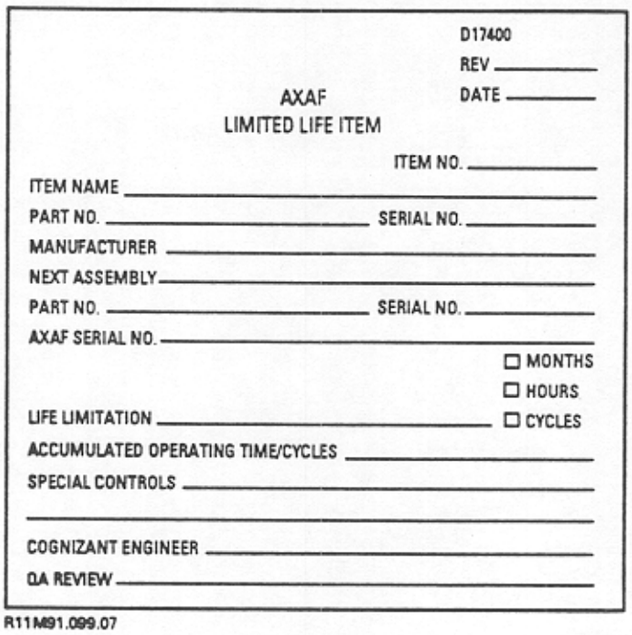

D17400
REV _____
DATE _____
AXAF
LIMITED LIFE ITEM
ITEM NO. _____
ITEM NAME _____
PART NO. _____ SERIAL NO. _____
MANUFACTURER _____
NEXT ASSEMBLY _____
PART NO. _____ SERIAL NO. _____
AXAF SERIAL NO. _____
☐ MONTHS
☐ HOURS
LIFE LIMITATION _____ ☐ CYCLES
ACCUMULATED OPERATING TIME/CYCLES _____
SPECIAL CONTROLS _____
COGNIZANT ENGINEER _____
QA REVIEW _____
R11M91.099.07

Figure 3.4.3.1 AXAF-I Limited Life Item Tracking Form

3.4.3.2 Storage and Handling - Sensitive Items

The effects of storage, shelf-life, packaging, transportation, handling, and any required maintenance for each spacecraft component will be discussed at the component design reviews. This includes any controls required to minimize the effects of storage and handling. This analysis is provided by the responsible design engineer, supported by test, materials and processes, quality, safety, packaging, handling, and transportability specialists, as necessary.

Factors to be considered include:

- The effect on AXAF-I hardware of the designated ground storage period. This includes defining any requirements for periodic operation, inspection, or testing while in the storage mode.
- Identification of items requiring special environmental controls during storage, handling, or transport.
- Identification of storage age-sensitive items which may require periodic maintenance or replacement.
- Identification of any special packaging requirements or handling precautions. This includes mismating prevention, consideration of human factors, ease of access, and safety hazard control.

3.5 PARTS STRESS ANALYSES

TRW will perform derating compliance analyses on EEE parts to assure conformance with MIL-STD-975. (The TRW Electronic Components Handbook (ECH) and its companion subcontractor document (DO2700) comply with MIL-STD-975.) Stress levels calculated will reflect worst case conditions of electrical and thermal stresses. Stress level versus rating data will be provided by the Responsible Design Engineers per DR SE26 in advance of component CDRs. Reliability and PM&P personnel will review this data for derating compliance. Junction temperature computations will use the unit's maximum acceptance test temperature as the components baseplate temperature. Parts identified as not meeting the derating criteria will either require a waiver by the AXAF-I Parts, Materials and Processes Control Board or replacement with a different part. Any changes to part deratings will be reflected in ECP and CCB documentation.

3.6 WORST CASE ANALYSES

Worst case analyses will be performed for critical design parameters that could degrade AXAF-I performance. Adequacy of design margins will be demonstrated by analyses and/or test for optics, electromechanical and mechanical items and electronic circuitry.

This analysis ensures that adequate circuit margins exist for the effects of piece part tolerances, aging, radiation effects and temperature. The TRW Electronic Components Handbook (ECH) identifies tolerances for temperature and end-of-life effects in worst-case analysis. Final worst-case values for tolerance, life, temperature and radiation effects are root-sum-square values. For AXAF-I, accumulated radiation dose for a 5 year mission, and aging and environmental effects for four years in storage, followed by a 5 year mission, will be evaluated.

Circuit segments will be examined considering piece parts to be at worst-case tolerances and:

- Input/output signals assumed to be at worst-case conditions.
- Transient effects considered.
- Power supply voltage and frequency shifts considered.
- Rise-time and fall-time tolerances applied and logic race conditions investigated for digital circuitry.

For most digital circuits, only power supply margins and compliance with fan-/fan-out maximum specifications must be examined. The worst-case analysis will be available at CDR, with any changes reflected in CCB documentation. Any out-of-tolerance conditions will be identified along with the recommended corrective action. Hardware may utilize previously-generated worst-case analyses if the AXAF-I mission duration has been taken into account. Responsible design engineers will provide the worst case analysis data. Independent design specialists will review the content for technical adequacy at the component-level CDR's.

3.7 TREND ANALYSES

Trends of critical parameters of individual components will be monitored during the integration and test phase. The purpose is to show that the hardware will remain within specifications over 15 years. Trend analysis data for the parameters will be included in the data package for the Flight Readiness Review.

The identification of critical parameters to be monitored will be the responsibility of AXAF-I system/subsystem engineers and will be provided by CDR. Test set software and procedures will then reflect the requirement to track these parameters and their limits during component and higher-level testing and to review trends at pertinent Test Review Boards. Mission Operations personnel will monitor trends of these parameters after launch.

Suspect or adverse trends encountered during ground testing will be documented as potential nonconformances and will be processed through the Problem Reporting System of Section 3.15. Such occurrences on orbit will be handled in accordance with the Mission Operations Plan for actions to be taken in response to red or yellow limits violations.

3.8 SPECIAL ANALYSES

Reliability personnel will perform sneak circuit analysis to assure that the system's fault tolerance is not adversely impacted by unexpected modes of operation. This effort will verify that responses to stimuli such as commands are not accompanied by inadvertent parallel effects. The effort will be focused on power distribution circuits, critical signal cross-strapping, command paths, redundancy activation, and manned-interface areas. Emphasis will be applied to safety-critical components. Operating paths will be traced into components to

sufficient depth to assure that inadvertent parallel operation or inhibiting of desired operation will not occur. Clue lists will be utilized to help identify suspect areas. An example of a suspect sneak circuit is an H-pattern circuit having two power sources and two grounds.

This analysis will be coordinated with the FMEA, PA02, and the System Hazards Analysis, SA04. It will be conducted during the detail design phase of the AXAF-I program and will be delivered as part of PA02 prior to CDR.

3.9 SOFTWARE ASSURANCE

Software Assurance for AXAF-I is described in PA14, Software Quality Assurance Plan.

Reliability personnel will perform the Hardware/Software Interface Analysis described in Section 3.4.1. Software problem reporting activities are described in PA14.

3.10 MAINTAINABILITY AND HUMAN-INDUCED FAILURE

Maintainability considerations for AXAF-I will consist of assuring prelaunch accessibility of components. Reliability personnel will also review fault diagnosis capability and possible human-induced errors as part of the FMEA/CIL effort.

3.11 ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL (EEE) PARTS

Selection, specification, qualification, and application requirements for AXAF-I parts are described in the AXAF-I EEE Parts Program Plan. This activity is the responsibility of the AXAF-I Parts, Materials, & Processes Organization. AXAF-I Reliability personnel perform the following tasks in support of the parts control effort:

- Participate in the AXAF-I Parts, Materials, and Processes Control Board (PMPCB) activity.
- Monitor derating compliance.
- Assure piece part failure analysis.
- Review for part failure trends.
- Review Alerts generated by the Alert system.
- Participate in parts retrofit decisions.
- Request parts specialist support as necessary at Failure Review Board meetings.
- Assure existence of a system for control of traceability of parts per the AXAF-I Quality Assurance Plan.

Reliability personnel will recommend the following types of corrective action through their membership and vote at the PMPCB meetings and FRBs:

- Provide additional usage justification data (history, test results)
- Require substitute part (larger capacity, standard part)
- Retrofit parts (based on failure analysis trends)
- Implement additional inspection or test provisions (critical item controls)

3.12 MATERIALS AND PROCESSES

The AXAF-I Materials and Processes Control Plan defines the requirements for materials selection and application review. This activity is the responsibility of the AXAF-I Parts, Materials, and Processes Organization. AXAF-I Reliability personnel interface with the materials control effort as follows:

- o Materials and Processes specialists provide support for design audits, troubleshooting investigations, and Failure Review Board meetings, where necessary.
- o Materials and Processes specialists participate in discussions of safety hazards, fatigue life, refurbishment questions, packaging reviews, outgassing effects, etc.

3.13 REVIEW OF EEE PACKAGING

Review of each AXAF-I component's packaging design will be undertaken at component CDRs by Product Engineering. Pertinent data to be included in the individual design review packages includes:

- o Layout of PC cards and stacking
- o Placement, mounting, and interconnection of EEE parts
- o Thermal and dynamic provisions
- o Electrostatic discharge (ESD) considerations
- o Ease of inspection
- o Conformal coating, substrates, and heat sinking

3.14 DESIGN REVIEW PROGRAM

The AXAF-I design review program contains three categories:

a) Program Milestone Reviews - The Program milestone reviews (SRR, PDR, CDR, DCR, FRR, etc.) as defined in DR CM05 and the Program Schedule.

b) Design Audits - These reviews are PDAs and CDAs of AXAF-I subsystems and components and represent detailed reviews of the hardware and software in preparation for the system-level PDR and CDR of (a).

c) Subcontractor Design Audits/Reviews - These audits/reviews are held at subcontractor facilities and support the System-level PDR and CDR of (a). The number of audit/reviews held (one or two) will be based upon the maturity of design and extent of the design modifications required for AXAF-I.

Items common to all of these audit/reviews are a meeting notice and agenda, data package, presentation material, minutes, action items, and closeouts. MSFC requirements for the program milestone reviews are as defined in DR CM05. Additional details regarding agenda sequence, committee participants, specific dates, and action item protocol for the program milestone reviews will be coordinated between MSFC and TRW prior to each review.

MSFC will be invited to attend TRW design audits and subcontractor design audits/reviews. PAR 700-272 describes the requirements established by TRW for subcontractor design audits/reviews.

Design review activities performed by TRW reliability personnel fall into three areas:

a) Administrative duties

b) Input to data packages and presentation at design audits/reviews

c) Critique of designs during reviews

The policy for TRW design audit/review reliability activities is contained in the TRW Reliability and Maintainability Handbook, Policy and Procedure 7.0.

A summary of documentation requirements for design audits is shown in Figure 3.14-1.

DOCUMENT	RESPONSIBILITY	REQUIREMENTS
Master Schedule	Program Manager or Designee	As Issued or as Revised
Meeting Notice/Agenda	Design Audit Chairman	30 Days Prior to Meeting
Design Data Package	Responsible Engineer	10 Working Days Prior to Meeting
Presentation Vugraphs	Responsible Design Engineer	At Beginning of Meeting
Action Item Summary	Design Audit Secretary	2 Working Days After Meeting
Meeting Minutes	Design Audit Secretary	10 Days After Meeting
Closure Response	Assignees	As Scheduled. Otherwise No Later Than 30 Days After Meeting

Figure 3.14-1 Design Audit Documentation

The data package contents for TRW design audits is shown in Figure 3.14-2.

The design audit requirements, the equipment covered, the committee assignments, and the conduct of the audits are established by the individual design audit chairman in conjunction with the responsible project manager.

Item	Due at PDA	Due at CDA
Functional Description (Hardware photos or exhibits where possible)	P	F
Block Diagrams, Schematics and Mechanical Configuration	P	F
Extent of New Design & Prior Program History	F	N
Requirements (include source) vs. Capabilities (include how verified)	P	F
Interface Compliance Data	P	F
Review of Action Items, Agreements, and Alerts from prior design audits	F	F
Problem and Risk Areas and Proposed Resolution	P	F
Analyses (as appropriate)		
Tradeoff Studies (including predictions, where applicable)	F	N
Electrical (power, commands, TLM, signals)	P	F
Stress and dynamics/mass properties/mechanical tolerance	P	F
Thermal	P	F
EMC/EMI	P	F
Performance (Incl. Test Results)	P	F
Worst-Case	P	F
Design Life Verification & Limited Life Items List	P	F
Derating Compliance	P	F
FMEA and Single Point Failure/Critical Items List	P	F
Environmental Effects and Protective Measures	P	F
Radiation Analyses, as required	P	F
Hazard Analysis/Hazard Reports	P	F
Maintainability and Human Engineering	P	F
Failure History (this and prior-related programs)	P	F
Previously-Qualified hardware data	F	N
Test Equipment	P	F

Figure 3.14-2 Design Audit Data Package Contents

Item	Due at PDA	Due at CDA
Product Design and Packaging Data	P	F
Indentured Drawing List	P	F
PM&P Lists, Specifications, & Approval Status	P	F
ALERTS (PM10)	P	F
Handling/Storage Requirements and Control	P	F
Manufacturing Drawings	P	F
Manufacturing Plan	P	F
Test Plans	P	F
Inspection Points, Traceability Plans	P	F

Legend:

P = Preliminary
F = Final
N = No Requirement

Figure 3.14-2 Design Audit Data Package Contents (Continued)

"Action Items" are assigned during the audit when items are noted which require significant effort outside the review. Action items and due dates are formally assigned by the Design Audit Chairman. The action items are recapped at the end of the audit session. Assignees will be given a copy of the action items.

"Agreements" are recorded during the audit when items are accepted as being a particular individual's responsibility, but it is desirable that it be a matter of record.

"Alerts" are noted when cautionary items arise. As an example: "Alert-System integration procedures require a caution notice of sequential power turn-on is necessary to prevent damage to ..."

Formal response by memorandum from the action item assignee is required to "close-out" each action item.

3.15 PROBLEM/FAILURE REPORTING AND CORRECTION

3.15.1 Introduction

Nonconformance control begins with procurement and continues through receiving inspection, manufacturing, test and launch activities. Control of defects found in receiving and in-process inspection, non-test discrepancies, and material review board (MRB) activities are the responsibility of Quality Assurance and are described in the Quality Assurance Plan, PA01. Reporting on parts and materials problems is the responsibility of Parts, Materials and Processes (PM&P) personnel and is delineated in the

Parts and Materials Program Plans, PA07 and SE04. Test discrepancy control is the responsibility of the reliability organization. Software problem reporting is described in Software QA Plan, PA14.

TRW uses a computerized closed-loop failure reporting system to record and track test failures from the time of occurrence through Failure Review Board closeout and beyond. This system provides:

a) A detection method for alerting activities within Quality Assurance, Reliability, Engineering, Manufacturing, Test and Program Management of possible failure conditions.

b) An analysis capability for establishing cause, significance, effect, and corrective action for failures.

c) A method for feedback of corrective action requirements to the procurement, design, manufacturing, test, and handling organizations.

d) A computerized data retrieval system for reporting individual failures, compiling failure trends, providing status summaries, and storing historical failure experience.

This system will be implemented in accordance with the requirements of NHB 5300.4(1A-1), Section 1A315, and DR PA11. Reliability participates in the failure reporting process by performing the following:

- Review of initial nonconformance reports

- Participation in the troubleshooting and failure analysis; documentation of the failure analysis; participation in defining and implementing the corrective action (including impact on past and future hardware); assuring that over-stress and trend analyses have been completed.

- Conducting an AXAF-I Failure Review Board (FRB) to disposition failure reports, assure the closeout of the FRB assigned action items; and preparation of documentation submittal to MSFC.

Definitions of terms associated with the nonconformance/failure reporting system are as follows:

a) Failure - The inability of a system, subsystem, component, or part to perform its required function within specified limits, under specified conditions for a specified duration.

b) Nonconformance - A condition of any article or material or service in which one or more characteristics do not conform to requirements. Includes failures, discrepancies, defects, and malfunctions.

c) Recurrence Control Action - Action taken to prevent recurrence of a nonconformance.

d) Remedial Action - Action to correct a nonconformance of an article or material.

e) Unsatisfactory Condition - Any defect for which engineering resolution is required and which requires recurrence control beyond the specific article under consideration. Included in this definition are conditions which cannot be corrected to the specified configuration using the standard planned operations or an event which could lead to a failed condition but does not currently affect the function of the article such as contamination, corrosion, workmanship requiring an engineering disposition, etc.

f) Component - Black box, unit, major assembly.

3.15.2 Hardware and Documentation Flow

Figure 3.15-1 illustrates the hardware and documentation flow for a test failure or discrepancy from the time of occurrence until it is closed out.

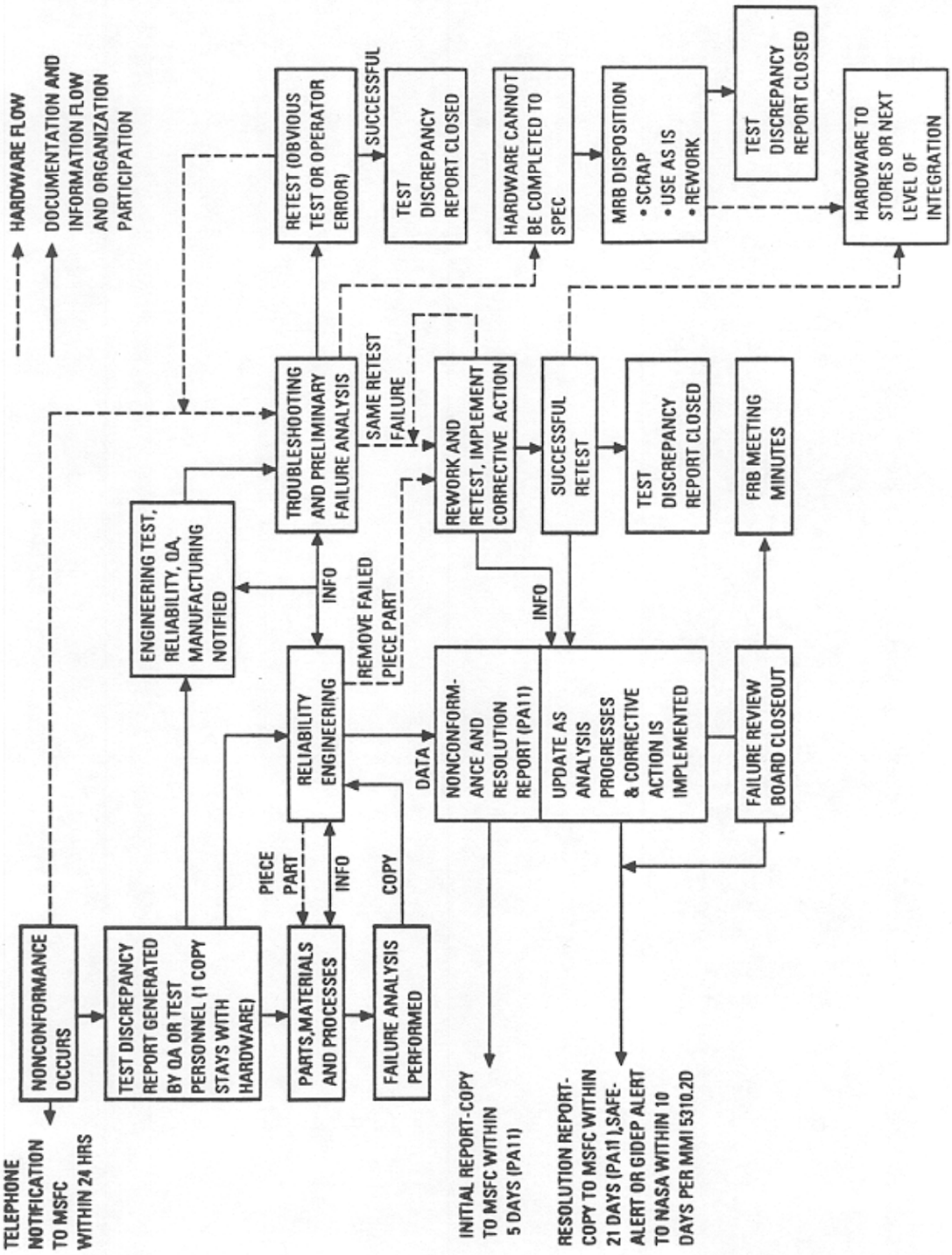


Figure 3.15-1 Nonconformance Reporting Flow Diagram

Samples of the reporting forms used in the nonconformance reporting system are shown in Figures 3.15-2 and 3.15-3.

- Figure 3.15-2 is the Test Discrepancy Report (TDR) which is generated for TRW in-house failures to travel with the hardware from the time of the failure. The nonconformance identification and initial findings are recorded on this form. One copy of this report stays with the hardware as it proceeds through troubleshooting, rework, and retest. Additional copies are distributed to AXAF-I reliability, the component engineer, and the computer data files.

- The Nonconformance and Resolution Report is shown in Figure 3.15-3. This report is generated for both in-house and subcontractor failures and is submitted to MSFC within 5 days of the nonconformance. Final results (or a status) of the failure analysis and corrective action are subsequently entered onto this report and are forwarded to MSFC within 21 days of the nonconformance.

NOTE: Figure 3.15-3 shows an existing TRW report which will be modified to provide the data required by DR PA11.

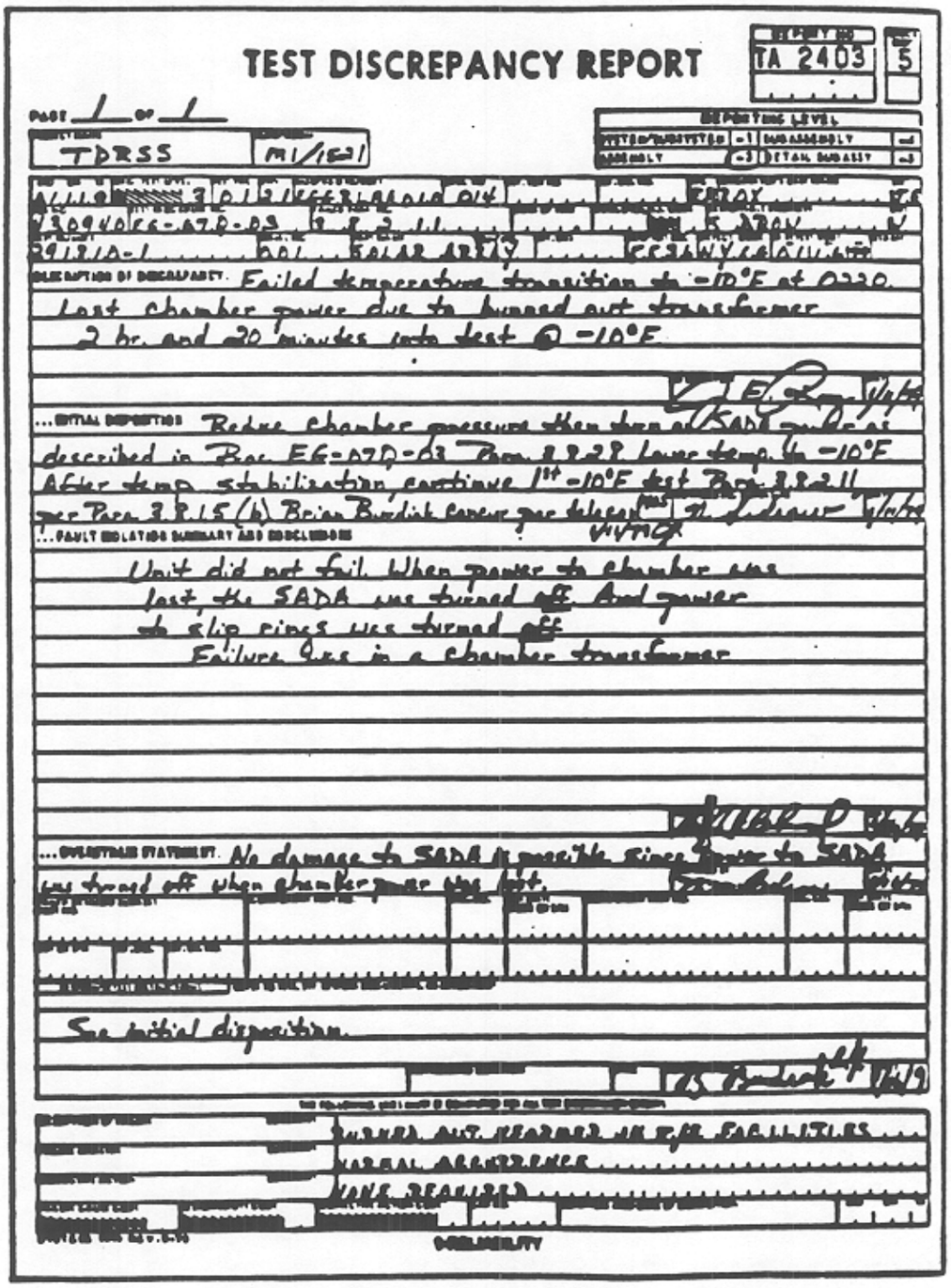
3.15.3 Scope

Flight and qualification hardware problem reporting begins when a component enters acceptance or qualification testing and continues through module and CEI testing and launch.

Nonconformances associated with Government Furnished Equipment (GFE) flight hardware will be documented on a Nonconformance Report, beginning with Receiving Inspection. This report will then be forwarded to MSFC for the necessary follow-up action. It will contain a listing of each discrepant GFE hardware item, observed anomaly, and date of occurrence. Details on the GFE failure analysis, corrective action, and closeout will be the responsibility of the GFE supplier.

Nonconformance reporting related to support or test equipment will be conducted for all instances where flight hardware or personnel are impacted.

EXAMPLE



TEST DISCREPANCY REPORT

TA 2403

5

TDRSS

Failed temperature transition to -10°F at 0220. Lost chamber power due to burned out transformer 2 hr. and 20 minutes into test @ -10°F

Reduce chamber pressure when down at SADA can be as described in Proc EG-A7D-03 Para 3.2.2.2 Lower temp to -10°F After temp stabilization, continue 1st -10°F test Para 3.2.2.11 per Para 3.2.15 (b) Brian Burdick Power was delayed

Unit did not fail. When power to chamber was lost, the SADA was turned off And power to slip rings was turned off Failure was in a chamber transformer

No damage to SADA is possible since power to SADA was turned off when chamber power was lost.

See initial disposition.

Figure 3.15-2 Test Discrepancy Report

NONCONFORMANCE AND RESOLUTION REPORT*			07/15/86		NUMBER TB9639
DATE INITIATED	09/26/80	TEST TYPE	ACCEPTANCE	CRITICALITY	MAJOR
DATE CLOSED	02/25/81	ENVIRONMENT	ROOM AMBIENT	FAILURE CAUSE	DESIGN ERROR
ORIGINATOR	KINZEL J	TEST PROCEDURE	87041-990	RESPONSIBILITY	SSD SUPPLIER
RELIABILITY ENGINEER	KINZEL J	PARAGRAPH NO.	5.7	CORRECTIVE ACTION	DESIGN/DRAW CHANGE
RESPONSIBLE ENGINEER	OHMAN C				

TEST LEVEL 3 SUBSYSTEM: TELEMETRY TRACK & COMMAND (TT&C)

TST LVL	PART NO.	PART NAME	SERIAL NO.	MANUFACTURER
ASSY/BOX/UNIT	291576	CTU	001	
PIECE PART				GULTON

DESCRIPTION OF FAILURE: EXCESS CURRENT DRAWN BY POWER SUPPLY

THIS FAILURE OCCURRED AFTER CTU S/N 001 WAS RETURNED TO GULTON FOR INCORPORATION OF OUTSTANDING ECOs AND FOR PINO TESTING OF SELECTED NSC MICROCIRCUITS. DURING THE POWER SUPPLY SHORT-CIRCUIT TEST, THE EXTERNAL POWER SUPPLY WAS FOUND TO BE DRAWING EXCESS CURRENT AND SHUT OFF.

FAILURE ANALYSIS: INDUCTIVE KICKBACK FAILED VOLT REG LM723

THE PROBLEM WAS TRACED TO U4 ON AN 87041-100-02, S/N 104, AN E1432 (LM723) VOLTAGE REGULATOR (LDC 7832, NSC), THE PART WAS FOUND TO HAVE A SHORTED BASE-TO-EMITTER JUNCTION (PINS 1 AND 10) AND AN OPEN BASE-TO-COLLECTOR JUNCTION (PINS 8 AND 10). THE LM723 (E1432) FAILURE WAS CAUSED BY INDUCTIVE KICKBACK OCCURRING WHEN RELAY CONTACTS BOUNCE DURING CHARGING OF THE L-C INPUT FILTER ON THE PLUS 5-VOLT SWITCHING REGULATOR. THE INDUCTIVE ENERGY WAS ABSORBED IN THE 0.1 MICROFARAD CAPACITOR AT PIN 8 OF THE LM723 MICRO-CIRCUIT AND THE LM723. THE ENERGY WAS SUFFICIENT TO DAMAGE THE CURRENT LIMIT TRANSISTOR WITHIN THE LM723.

CORRECTIVE ACTION/COMMENTS: DESIGN CHANGE. ADDED DIODE 1N3611

A 1N3611 (E1480) PROTECTION DIODE HAS OR WILL BE ADDED TO ALL AN87041-100 BOARDS. THE DIODE IS REFERENCED AS CR34 IN ECO #87041-305. SIR #N80430 INDICATES THAT THE 1N3611 DIODE IN THIS APPLICATION IS MORE THAN ADEQUATE TO PROTECT THE EMITTER-BASE JUNCTION OF C14 (LM723). WORST CASE ANALYSIS INDICATES THAT INITIAL POWER APPLICATION WILL CAUSE THE WORST CASE CURRENT THROUGH THE KICKBACK DIODE TO BE 4.32 AMPERES, WHICH WOULD OCCUR WITH CONTACT BOUNCE AT 0.5 MILLISECONDS. WITH A 3X SAFETY FACTOR ON DURATION, THE CURRENT WOULD THEN FALL LINEARLY TO 0 AFTER 0.75 MILLISECONDS. THE 1N723 DIODE CAN HANDLE A SURGE CURRENT OF 30 AMPERES IN 8 TO 10 SECONDS FOR A 1 MINUTE DURATION. IN ADDITION TO THE DIODE, THE LM723 (U4) IN EACH CTU HAS BEEN OR WILL BE REPLACED EXCEPT REVIEWED THE CTUs AND RCTUs CIRCUIT CONFIGURATIONS TO DETERMINE IF STORED INDUCTIVE ENERGY COULD BE DISSIPATED THROUGH PAIRS WHICH CAUSE DEVICE OVERSTRESS. GULTON FOUND THAT SIMILAR FAILURE MECHANISMS DO NOT EXIST IN EITHER THE CTUs OR RCTUs. REFERENCES: GULTON FAR #8704-032; GULTON FAR #8704-031; SIR #80430). THIS ITEM WAS CLOSED IN FRB-22 ON 02-25-81.

*TO BE ADAPTED TO THE REQUIREMENTS OF DR PA11

Figure 3.15-3 Nonconformance and Resolution Report

3.15.4 Nonconformance Reporting Responsibilities and Procedures

Quality Assurance has the responsibility for ensuring that a TDR is properly prepared and contains all the pertinent details for each discrepancy. The TDR shows the type of test being conducted (i.e., acceptance, bench, qualification, vibration, thermal vacuum, etc.) and the cumulative operating time (or cycles) at the time of the test discrepancy.

Failure analysis by reliability and quality engineering personnel and the responsible design engineer will commence prior to removal of failed hardware from the test set-up. Detailed troubleshooting will be approved at that time and coordinated with the responsible engineer or his designee. The troubleshooting and teardown record (TSTR) is used to document each step of the troubleshooting and rework operations. The TDR documents the troubleshooting sequence, fault isolation logic, overstress analysis information, and rework and retest instructions for the discrepant hardware. Reliability personnel participate in the retest identification and are responsible for follow-up to ensure the corrective action is implemented and effective.

All parts, e.g., resistors, transistors, integrated circuits, removed from the hardware, are identified by Parts Replacement Records (PRR), and are retained for failure analysis. The failure analysis of a piece part is initiated as a cooperative effort between the Responsible Design Engineer, Reliability Engineer, and the Parts, Materials and Processes (PM&P) Engineer using a Failure Analysis Request/Report. Pertinent details concerning the circuit application, test conditions, part behavior, etc. are supplied for the piece part failure analysis.

Nonconformance reporting (PA11) to MSFC will include, as a minimum, the following:

a) All failures of Criticality Categories 1, 1R, 1H, 1HR, 2, 2R, 2P, and 2PR and functional failures of Category 3 beginning with "line replaceable unit" level of qualification/acceptance testing will be reported to MSFC.

b) Deleted.

c) Each problem report will be limited to a single occurrence of a nonconformance.

d) Twenty-four hour notification (telephone) will include:

- o Uniquely identifiable report number
- o Date of occurrence
- o Nature of problem
- o Worst case criticality
- o Nonconforming Item (NCI)
- o NCI P/N

- o Location
- o End Item S/N
- o Test or operation

e) Formal report within five days will include:

1. Unique identifiable report number (same as 24 hour report)

2. Date of occurrence

3. Complete description of problem including comparison of expected events with actual events (or results).

4. Failure mode criticality (update)

5. Functional criticality assignment

6. Test operation being performed at time of occurrence (acceptance, final checkout, countdown), if applicable.

7. Nonconforming article: Part number, part name, serial number, manufacturer, lot number (as applicable).

8. Next higher assembly: Part name, part number, serial number, manufacturer (as applicable).

9. Test Article: Part number, part name, serial number, manufacturer.

10. Indication of whether problem is a failure or an unsatisfactory condition.

11. Indication of whether problem is due to design deficiency or manufacturing inconsistency (if known).

12. List of test documents (if applicable).

13. Preliminary cause of problem (if possible).

14. Remedial action taken.

f) Problem resolution report within 21 days (or upon problem resolution) will include:

1 through 14 above.

15. Date of resolution.

16. Actual cause of problem based upon failure analysis

    a. If explained, effect on mission should it reoccur.
    b. Workaround available.

17. Corrective action implemented to prevent recurrence.

18. Disposition of failed hardware.

19. Identification of failure mode/cause as new or previously experienced.

    - If previously experienced, will state quantity of previous occurrences on specific hardware.

20. Identification of specific CIL page applicable to the Criticality 1, 1H, 1R, 1HR, 2, 2R, 2P, or 2PR failure modes.

21. Accumulated time/cycles for item.

22. Problem report numbers that relate to same problem.

23. Vehicle effectivity for problem resolution.

g) Problem closure will include:

1. Closed copy of problem report.
2. Copy of test reports-studies/presentations.
3. Failure analysis reports.
4. Implementation Change Paper.

h) In addition to the normal distribution, a copy of the reports will be addressed to:

Problem Assessment Center
Marshall Space Flight Center
Building 4708, Room 249
Pitney Bowes FAX 205-544-5872
Telephone 205-544-7459

i) A letter format may be used.

j) Updated reports are required until satisfactory closeout/explanation occurs.

3.15.5 Corrective Action

After the cause of a failure has been identified, recommendations for corrective action are developed and referred to the appropriate project disciplines for implementation. Corrective action for parts problems involves the PM&P Manager, Component Engineer, Reliability Engineer, and in the case of "purge" questions, the Project Manager and MSFC. For a design problem, the corrective action is the responsibility of the Responsible Design Engineer with assistance from Reliability Engineering. When the failure investigation isolates the problem to a workmanship or test problem, the effort may require support from the responsible Quality Engineer, Component Engineer, Manufacturing Engineering, Testing, and Materials and Processes specialists.

3.15.6 Failure Review Board

Formal closeout of failure analyses and recommended corrective action occurs at the TRW Failure Board (FRB). The FRB (which nominally meets monthly) reviews all analyses of test discrepancies. The FRB meeting is chaired by the Reliability Manager (or the Product Assurance Manager) who is responsible for assigning action items and following up on corrective actions. Meeting minutes are prepared by the FRB secretary and distributed to all attendees. The FRB includes representatives from Design Engineering, Reliability, PM&P, Quality Assurance, Manufacturing, Assembly and Test, and Project Management, as required. Local MSFC representatives are invited.

3.15.7 Subcontractor Failure Reporting

Subcontractor failure reporting requirements are imposed through the AXAF-I PAR document. These requirements delineate time constraints (compatible with TRW's reporting obligations to MSFC) upon the subcontractor for initial notification to TRW, a preliminary failure report (i.e., subcontractor's format), and a final failure report closeout. Additionally, the status of open failures must be reported in the subcontractor's monthly progress reports.

Subcontractor failure reports will be integrated into the AXAF-I reporting system by TRW. All subcontractor failure report closeouts must be approved by the TRW AXAF-I FRB. Subcontractor failure reporting documentation will be transmitted to MSFC by TRW.

3.15.8 Relationship to Quality Assurance

The system described above reflects the reporting, analysis and corrective action for failures resulting from test of hardware above the piece part level. Problems detected in parts inspection and discrepancies other than test failures are handled by the Quality Assurance (QA) nonconformance control system as discussed in the Quality Assurance Plan (PA01). There are similarities in the two systems. Reliability failure reporting uses the TDR and Nonconformance Resolution forms, while Quality Assurance uses a Nonconforming Material Report. Data is entered into a computerized data base for both disciplines. QA discrepancies are closed out by the Material Review Board (MRB).

3.16 ALERTS

TRW has an established system for handling ALERTS or Safe ALERTS in accordance with DR PA10 and NHB 5300.4(1D-2). All ALERTS received from external sources are evaluated by PM&P and Reliability personnel for AXAF-I program impact, i.e., ALERTS received from other TRW projects, GIDEP, NASA, Aerospace, and Industry sources. ALERTS are processed by the TRW GIDEP representative and AXAF-I Parts and Materials Manager. NASA

ALERTS will be responded to within 21 working days by the AXAF-I PM&P Manager.

SAFE-ALERTS are routed to the cognizant engineering personnel, Health and Safety personnel, and AXAF-I Safety Manager. SAFE-ALERTS are reviewed and responded to by the AXAF-I Safety Manager.

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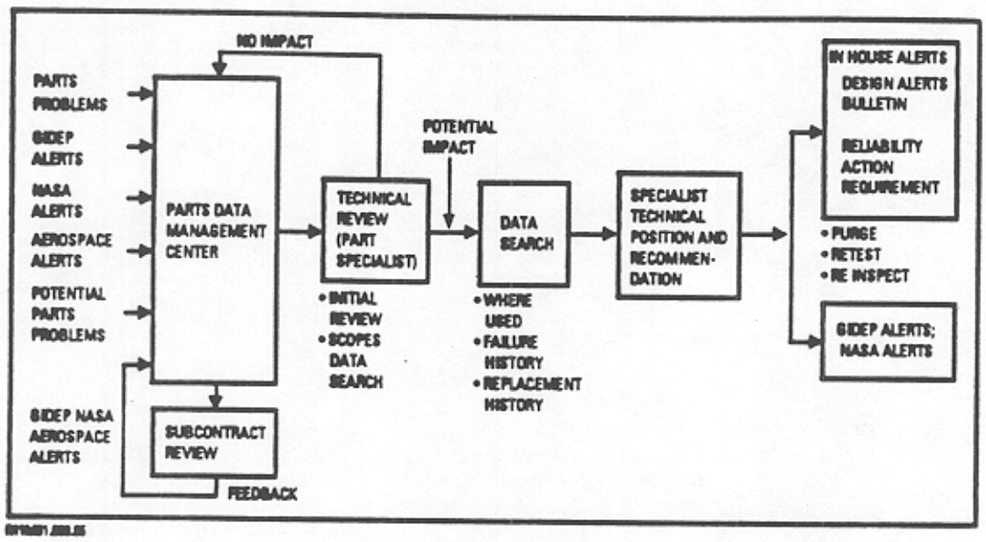
Part and Material Alerts of a non-safety nature are handled as shown below:



A feature of this system is the engineering and manufacturing management involvement in high leverage part or material problems. When required, a TRW Reliability Action Requirement may be issued internally to control suspect parts or materials. Design Alert Bulletins are generated to describe possible design deficiencies. TRW-initiated Alerts considered worthy of possible NASA-wide circulation will be routed to MSFC for further action. MSFC, NASA, and TRW-initiated alerts are dispositioned per MMI 5310.2D. TRW's disposition of applicable parts or materials Alerts is reviewed at meetings of the AXAF-I Parts and Materials Control Board. Flowdown of these alert reporting requirements to Subcontractors is covered in the AXAF-I Product Assurance Requirements Document, PAR 700-272.

4 TESTING AND RELIABILITY EVALUATION

4.0 GENERAL

The AXAF-I test program is defined in the AXAF-I Verification Plan, VR01. This plan is developed by the Assistant Project Manager for Assembly and Verification, who has drawn upon the HST, OMV, TDRS, and GRO Verification Plans. The AXAF-I Verification Plan is reviewed and approved by all the AXAF-I program disciplines and is a Type 1 Data Requirements submittal to MSFC.

Reliability personnel participate in all phases of the project test program from the piece part level through test and mission operations. Activities include inputs to test plans, review of test procedures, anomaly investigations, participation in retest and retrofit decisions, and test effectiveness studies.

Reliability data is derived from the following sources:

- Tests of parts and materials.
- Environmental and functional tests of qualification or acceptance hardware.
- Historical data on TRW flight spacecraft contained in TRW's orbital data bank.

4.1 RELIABILITY EVALUATION PLAN

The plans for piece part, component, and higher level testing (developmental, life testing, qualification, and acceptance tests) are described in the AXAF-I Verification Test Plan, VR01.

Test results will be analyzed by Reliability personnel and used to update the FMEA, CIL, MTBF's, life ratings, etc.

Reliability reviews testing at the different levels of hardware assembly and contributes as follows:

<u>AXAF-I Level Testing</u>

- Assurance that redundant and alternate paths are tested.
- Assurance that enough test time is accumulated for each component.
- Assurance that proper components are "on" during simulation of various mission phases.
- Review of types of environmental exposures planned.
- Assistance in data review to identify any abnormalities.
- Assurance of testing of any single point failure modes.

- Identification of any testing results that are at variance with the FMEA and making necessary revisions.
- Participation in retest decisions and component removal issues.
- Participation in Pre and Post-Test Critiques.
- Assurance of identification and monitoring of parameters indicating subsystem and component performance stability.

Reliability personnel participate in the activities shown below, as part of the AXAF-I test program:

Piece-Part Testing

- Review of burn-in hours and parts requiring burn-in/cycles.
- Review of overall screening matrix, i.e. PIND, X-Ray, Group B testing, etc.
- Review of age-limitations on parts to be used on the AXAF-I and re-inspection requirements.
- Review of FAR's (suspect part failure analysis reports).

Component Level Testing and Above

- Review of environments applied, parameters monitored during same, temperature ranges, transition rates, vibration time, etc.
- Review of burn-in time and spares conditioning requirements for components.
- Participation in decisions to failure analyze suspect piece-parts.
- Performance of trend analysis as necessary.
- Participation in identifying nature and extent of retest required after test discrepancies have occurred.
- Review of retest results to assure that the corrective action taken was correct.

Control of unscheduled activities during test is described in the AXAF-I Quality Assurance Plan. Safety incidents are handled as described in the Safety Plan, SA03.

TRW Operational Safety personnel review all planned operations at the AXAF-I testing level for unsafe conditions or possible hazards.

4.2 TESTING

The AXAF-I Verification Plan contains the Qualification Matrix showing which components will be qualified-by-similarity, protoflight-tested, or subjected to full qualification. Reliability personnel review this matrix to assure that items proposed for qualification-by-similarity have demonstrated the capability to withstand AXAF-I's 5-year environmental exposure.

Reliability personnel also review piece part qualification plans as participants in the AXAF-I Parts,Materials, and Processes Control Board.

Components subject to wearout may be subjected to mechanical cycling, temperature cycling, load cycling, or stress testing to demonstrate their capability for this application. The AXAF-I Verification Test Plan reflects current plans for such testing.

4.3 RELIABILITY ASSESSMENT

Test results from Qualification and Acceptance testing will be evaluated for correlation to the FMEA.

4.4 RELIABILITY INPUTS TO READINESS REVIEWS

Reliability personnel will provide failure history and other pertinent data in support of Readiness Reviews.

4.5 RELIABILITY EVALUATION PROGRAM REVIEWS

Reliability personnel will participate in AXAF-I Test Review Boards.